Ustilaginales of Hawaii

YRJÖ MÄKINEN[1]

THE SMUT FLORA of the Hawaiian Islands is relatively limited. Stevens (1925) reported only two species, *Sorosporium paspali* and *Sphacelotheca monilifera,* on native plants, and six other species on introduced hosts. Parris (1938) added one introduced host for *Sorosporium paspali,* two additional species, *Ustilago bromivora* and *U. zeae,* on introduced plants, and (in 1939) one more species, *U. utriculosa.* Later he mentioned an undetermined *Ustilago* species on *Cynodon dactylon* (Parris, 1940:63). Petrak (1953) added one further collection of *Graphiola phoenicis.* This is all that has been written on the Hawaiian smut fungi. The present paper adds two more native species, *Farysia caricis-filicinae* and *Thecaphora mauritiana,* neither apparently hitherto reported for the Pacific area, and two more species on introduced hosts.

The following list is based partly on my own collections, made during 1965 and 1966, and deposited in the herbaria of the Bernice P. Bishop Museum, Honolulu (BISH), and of the University of Turku, Finland (TUR). In addition, the specimens in the Bishop Museum and in the herbarium of the Botany Department, University of Hawaii (HONO), have been included in the present list, except the specimens cited by, and mostly collected by, Stevens, which form the bulk of these collections. Scrutiny of the vascular plant collections in the Bishop Museum revealed three specimens, and four additional specimens were found in the mycological collections of the Plant Quarantine Division, United States Department of Agriculture, Honolulu International Airport (HONQ).

The nomenclature mainly follows that of Lindeberg (1959). Spore sizes, unless otherwise stated, are means of 10 measurements from every specimen cited. In species with several specimens, this gives a fair estimate of the mean for the population. The information about elevation is sometimes approximate and mainly restricted to my specimens, but even so I consider it important, as this point is too often neglected in mycological collections. Most parasitic fungi have their own macroecological requirements, which may be somewhat different from those of the host. Decreasing temperature, correlated, for example, with elevation, is one of the main macroecological factors for the parasites.

Two abbreviations used in the lists of collections require explanation: M. = Y. Mäkinen; f.n. = field note without a preserved specimen.

[1] Department of Botany, University of Turku, Turku 2, Finland. Revised manuscript received October 21, 1968.

LIST OF HAWAIIAN SPECIES

Entyloma dactylidis (Pass.) Cif.
E. crastophilum Sacc.

On *Holcus lanatus* L.

HAWAII: Kilauea (Stevens, 1925:127).

MAUI: Haleakala Crater, Koolau Gap, at the western pali (6,620 ft), Sept. 11, 1966, M. 66-1725a.

Farysia caricis-filicinae Ito

On *Carex wahuensis* C.A.M. var. *rubiginosa* R. Krauss

HAWAII: Hawaii Volcanoes National Park, Mauna Loa Strip road, 1.5 miles from the start (4,500 ft), July 7, 1966, M. 66-1225.

About 20 specimens of the host occurred in this locality, but only two of them were strongly infected (Fig. 1), the others showing no sign of contamination. *Carex macloviana* var. *subfusca,* growing close to the infected specimens, was not infected. In spite of the careful search, I was unable to find the smut elsewhere, although the above variety is fairly common all over the surrounding area, and *C. wahuensis* var. *wahuensis* is the commonest member of the genus *Carex* in the Hawaiian Islands.

The taxonomy of the genus *Farysia* is at present in a quite hopeless state of confusion. The morphological differences between the spores of various species are small. Moreover, too much emphasis has been placed on the

FIG. 1. *Farysia caricis-filicinae* on *Carex wahuensis* var. *rubiginosa* (M. 66-1225).

size of the spores; taxonomic conclusions in parasitic fungi should never be based on averages from a single specimen only, as these are likely to be influenced by local conditions and may lead to great bias (see also what is said under *Thecaphora mauritiana*). Ciferri (1931: 73) for example, based the new species *Farysia americana* on the size difference (as compared with *F. olivacea*) only, without having any idea of the population variation ("Sporis 4–10μ. in diam., pro more 5–7μ., typice 6μ. diam.; caetera ut in *Farysia olivacea*"). Species based on the deviating size of a single collection may well represent the normal lower or upper end of variation.

In the present collection the size of the spores from 110 measurements is 6.24 ± 0.13μ × 7.18 ± 0.11μ. Of the "species" which occur in North America or Asia, *F. caricis-filicinae* Ito seems to fit the present collection best. The spore size given by Ling (1949*a*) for the type on *Carex cruciata* is 7.61 ± 0.09μ, and for a specimen collected in Kwantung by McClure (on *C. cruciata*) 8.21 ± 0.10μ. According to the description of Ito (1935), the spores are 6–11 × 6–7.5μ, mostly 8 × 6μ. Thirumalachar (1950) gives the following measurements for two specimens from eastern Nepal and the Khasi Hills: 6–10.3μ, mean 7.7μ. It seems probable that *F. caricis-filicinae* represents a real taxonomic group, separable from *F. olivacea. F. merrillii* (P.Henn.) Syd. (Sydow and Sydow, 1919) and *F. orientalis* Ling (Ling, 1949*b*) differ in the striate-verrucose epispore, the latter also in the irregular spores.

Graphiola phoenicis (Moug.) Poit.

On *Phoenix dactylifera* L. (some of the older records might refer to hybrids with *P. canariensis* Chab.)

HAWAII: Hilo (20 ft), July 6, 1966, M. (f.n.).

KAUAI: Kekaha, June 9, 1910, L. O. Larson (HONO).

OAHU: Honolulu, Sept. 15, 1909, L. O. Larson (HONO); Honolulu, 2 collections (Stevens, 1925:162); Honolulu, University Campus 1953, Petrak, and (50 ft) Oct. 18, 1965, M. 65-38a; Waikiki (20 ft), Oct. 30, 1965, M. (f.n.); Round Top, Puu Ualakaa Park (1,000 ft), Oct. 23, 1965, M. (f.n.). Probably much commoner than these few observations indicate.

Thecaphora mauritiana (Syd.) Ling
Tolyposporium mauritianum Syd.

On *Fimbristylis cymosa* R.Br. var. *pycnocephala* (Hilleb.) Kük.

HAWAII: south coast, Punaluu Beach Park (8 ft), July 11, 1966, M. 66-1315.

MOLOKAI: Kahaeokailio, May 24, 1918, J. F. Rock 14021 (BISH vasc.).

These two specimens fit fairly well with the description of Mundkuhr and Thirumalachar (1946), and with the somewhat vague description of Sydow (1939). Comparison with the type specimen of *Tolyposporium mauritianum,* collected by Shepherd in Mauritius in 1929 (IMI 44786) showed that these three collections were conspecific. Measurements of 100 spore

balls gave the following means and ranges: M. 66-1315: 38.8 ± 0.28μ (23–52μ); Rock 14021: 45.3 ± 0.34μ (31–62μ); Shepherd (IMI 44786): 31.6 ± 0.25μ (22–46μ). Mundkuhr and Thirumalachar (1946) give the values 27–55μ (mean 39μ). Although the measurements now recorded differ very significantly from those of the type specimen, they are not to be taken as indicating taxonomic differences because nothing is known about the variation of this character in the species. Moreover, climatic conditions often decisively affect spore size, as demonstrated, for example, in *Albugo candida* (Mäkinen and Hietajärvi, 1964), and thus taxonomic conclusions should never be based on deviations in spore size or spore ball size alone, without knowing the total range of variation. In my collection, the spores measure (200 measurements) 17.2 ± 0.15μ × 14.3 ± 0.19μ (ranges 13–20 × 11–18μ). Sydow (1939) gives 10–14μ for the spore size, and Mundkuhr and Thirumalachar (1946), 9–14μ. The number of spores in a spore ball varies from 2 to 31, with a mean of 13.57 ± 0.405 (200 spore balls); according to Mundkuhr and Thirumalachar, the spores number 10–14. Otherwise, the morphology of the spores and spore balls corresponds well with that of the type specimen, and with the description of Mundkuhr and Thirumalachar.

Thecaphora mauritiana was first described as *Tolyposporium mauritianum* by Sydow (1939), and transferred to *Thecaphora* by Ling (1950). Meanwhile, Mundkuhr and Thirumalachar (1946) described *Thecaphora fimbristylidis*, which is synonymous with *T. mauritiana*. So far it has been collected on *Fimbristylis monostachya* (L.) Hasskn., once in Mauritius and three times in Mysore, India. The distance from Hawaii to Mysore is approximately 12,500 km, and to Mauritius, 15,000 km. Probably the species has a wide distribution in tropical areas, but escapes notice because it is inconspicuous (Fig. 2).

FIG. 2. *Thecaphora mauritiana* on *Fimbristylis cymosa* var. *pycnocephala* (M. 66-1315).

Ustilago avenae (Pers.) Rostr.

On *Avena sativa* L.

OAHU: Honolulu (Stevens, 1925:127).

Ustilago bullata Berk.

U. bromivora (Tul.) Fisch.v.Waldh.

On *Bromus catharticus* Vahl

HAWAII: Waihee, 1938, K. Parris (HONO) (see Parris, 1938, 1939). The designation of Waihee on the island of Hawaii is uncertain; there is a Waihee on Oahu and also one on Maui.

On *Bromus breviaristatus* Buckl.

HAWAII: Saddle road, 7 miles southeast of the Kona road junction (5,000 ft), July 4, 1966, M. 66-1106.

On *Bromus* sp.

HAWAII: Kapapala, 1938–1939, K. Parris (HONO).

Ustilago cynodontis (Pass.) P.Henn.

On *Cynodon dactylon* L.

MOLOKAI: One Alii Beach Park (6 ft), Sept. 25, 1966, M. 66-2110; Kaunakakai, at Ed's TV and Radio Service (30 ft), Sept. 25, 1966, M. 66-2109.

OAHU: Honolulu, 2640 Dole Street (90 ft), Jan. 24, 1966, M. 66-165; Dole Street at Pineapple Research Institute (50 ft), May 20, 1966, M. 66-794; University campus, East-West Road and Correa Road (80 ft), July 27, 1966, M. 66-1364; upper end of Manoa Valley, Loulu Street (280 ft), July 26, 1966, M. (f.n.); Waialae Avenue and St. Louis Heights Drive (40 ft), Jan. 18, 1966, M. 66-111; Ala Moana and Atkinson Drive (5 ft), Oct. 19, 1965, M. 65-47; Kapiolani Boulevard and University Avenue (7 ft), Oct. 3, 1965, M. 65-6; McKinley High School athletic field, Sept. 30, 1959, G. Pearsall 24169 (HONQ; sub *Ustilago chloridicola*

on *Chloris radiata*); Honolulu, June 30, 1963, F. L. Madinger 37782 (HONQ). Kailua, June 8, 1960, L. M. Chilson 25099 (HONQ); at the Kailua Drive-in Theatre (80 ft), March 15, 1966, M. (f.n.). Kunia Road, 0.6 miles south of Kupehau Road (540 ft), Feb. 13, 1966, M. 66-520. Kamehameha Highway at Mililani Memorial Park (600 ft), Jan. 8, 1966, M. 66-38. Wahiawa, at the botanical garden (950 ft), May 8, 1966, M. (f.n.). Waialua, Mokuleia Beach, Crozier Drive (12 ft), Feb. 13, 1966, M. (f.n.). Poamoho, University experimental farm (660 ft), Jan. 8, 1966, M. (f.n.). Makua, roadside, Apr. 4, 1954, A. Chase (BISH). Southeast of Maili Beach Park, at Mapaloao Bridge (6 ft), Jan. 23, 1966, M. 66-157. Altitude range: 5–950 ft.

Ustilago cynodontis was first collected in the Hawaiian Islands in 1954 (probably the record of Parris, 1940:63, also refers to this species), but it has spread very quickly, and is now the commonest smut fungus in inhabited places, much more common than the list of specimens indicates. Especially in Honolulu, along Kapiolani Boulevard and elsewhere, it occurs in almost every patch where the host develops spikes, and is usually very abundant. Likewise it is very common in several places by Kunia Road and Kamehameha Highway between Pearl Harbor and Wahiawa. It deforms the spikes of the host completely. The interisland channels have delayed its spread to the other islands, but no doubt by now it could be found on most of them. On Molokai it was very abundant in both localities. The spores (from 15 specimens) measure on the average 6.36 × 6.75μ.

Ustilago jensenii Rostr.

U. hordei (Pers.) Lagh.; regarding the nomenclature of this species, see Nannfeldt in Lindeberg (1959:157).

On *Hordeum vulgare* L.

KAUAI: Kokee, at Ranger Station, March 21, 1935, H. L. Lyon (HONO).

OAHU: Honolulu, Apr. 25, 1913, H. L. Lyon 324 (Stevens, 1925:127).

Ustilago maydis (DC.) Corda

On *Zea mays* L. See Parris (1938). Recently observed on Oahu and Hawaii (M. Aragaki).

Ustilago monilifera Ell. and Ev.

Sphacelotheca monilifera (Ell. et Ev.) Clint.

On *Heteropogon contortus* (L.) PB.

LANAI: Kamao, Apr. 17, year? G. C. Munro 632 (BISH).

NIIHAU: Kaali, Jan. 1912, J. F. G. Stokes (BISH vasc.).

OAHU: Honolulu, southwest end of Waahila Ridge (350 ft), Nov. 9, 1965, M. 65-201; Diamond Head Road at the Coast Guard station (90 ft), Jan. 24, 1966, M. 66-103; Diamond Head, 1938–1939, K. Parris (HONO); see Parris (1939). Stevens (1925:127) mentions that this species was reported by Heller.

Ustilago paspali-thunbergii P. Henn.

Sorosporium paspali-thunbergii (P. Henn.) Ito

Sorosporium paspali McAlp.

On *Paspalum dilatatum* Poir. On imported seed; see Parris (1938).

On *Paspalum conjugatum* Berg.

OAHU: Tantalus (Stevens, 1925:125).

On *Paspalum orbiculare* Forst.

HAWAII: Kohala, Apr. 1925, Lee 105 (HONO).

MAUI: West Maui, MPC's Haelaau house (at the start of the Puu Kukui trail) (2,980 ft), Sept. 9, 1966, M. 66-1785.

OAHU: Honolulu, Waahila Ridge at the *Araucaria* plantation (1,000 ft), March 4, 1966, M. 66-440; Tantalus, junction of Pauoa Flats trail and Manoa cliff trail (1,940 ft), Aug. 21, 1966, M. 66-1554; Tantalus ridge, Sept. 5, 1909, H. L. Lyon (BISH). Koolau Range, Poamoho trail 1.6 miles from the crest (1,760 ft), Aug. 20, 1966, M. 66-1529; Waianaeuka, south fork Kaukonahua, Dec. 9, 1945, D. P. Rogers 690 (BISH); Kawaiiki Ditch trail, at the start (1,200 ft), Apr. 30, 1966, M. 66-688, and at the dam (1,160 ft), May 14, 1966, M. 66-776. Waianae Range, Mokuleia, slopes of Mt. Kaala, spring 1912, C. N. Forbes (BISH).

Stevens (1925:125–126) mentions 7 collections from Hawaii, 1 from Kauai, 1 from Maui, and 12 from Oahu (specimens in BISH and HONO). Altitude range is 1,000–2,980 ft according to my specimens. Among the localities reported by Stevens (1925:125), however, are

Rainbow Falls and Kilauea on Hawaii, which give the approximate lower and upper altitude limits of 450 and 4,000 ft).

This species is the commonest smut in the Hawaiian Islands. It is often fairly inconspicuous, and is probably to be found everywhere at the higher elevations where *P. orbiculare* occurs. In the 28 specimens examined, the means of the spore dimensions ranged from 11.2 to 15.1μ in width, and from 14.0 to 17.5μ in length, the grand mean being 12.91 ± 0.18 × 15.68 ± 0.17μ. The spores are very finely warted; occasionally the warts occur on only one side of the spores, but this need not be taken to indicate that the smooth sides were originally pressed together.

Ustilago reiliana Kühn
Sphacelotheca reiliana (Kühn) Clint.

On *Sorghum* sp. See Stevens (1925:127): probably on Oahu.

Ustilago reticulata Liro
U. utriculosa (Nees) Ung.

On *Polygonum glabrum* Willd.
HAWAII: Waimea, Nov. 1937, K. Parris (HONO); see Parris (1939). The specimen has been destroyed, but there were enough spores attached to the envelope to check the identification.

Ustilago sorghi (Link) Pass.
Sphacelotheca sorghi (Link) Clint.

On *Sorghum* sp.
OAHU: Wahiawa (Stevens, 1925:127).

Ustilago striiformis (Westend.) Niessl

On *Holcus lanatus* L.
HAWAII: Hawaii Volcanoes National Park, end of the Mauna Loa Strip road (6,750 ft), July 7, 1966, M. 66-1235.

The total number of native species is 4 (*Farysia caricis-filicinae, Ustilago paspali-thunbergii, U. monilifera, Thecaphora mauritiana*), and of introduced species 11, with a total of 18 smut-host combinations. For 4 of the species I have seen no material. The following list gives the distribution of the species on the different islands (Ha, Hawaii; Ka, Kauai; La, Lanai; Ma, Maui; Mo, Molokai; Ni, Niihau; Oa, Oahu).

	Ha	Ka	La	Ma	Mo	Ni	Oa
Entyloma dactylidis	+	−	−	+	−	−	−
Farysia caricis-filicinae	+	−	−	−	−	−	−
Graphiola phoenicis	+	+	−	−	−	−	+
Thecaphora mauritiana	+	−	−	−	+	−	−
Ustilago avenae	−	−	−	−	−	−	+
Ustilago bullata	+	−	−	−	−	−	−
Ustilago cynodontis	−	−	−	−	+	−	+
Ustilago maydis	+	−	−	−	−	−	+
Ustilago monilifera	−	−	+	−	−	+	+
Ustilago paspali-thunbergii	+	+	−	+	−	−	+
Ustilago reiliana	−	−	−	−	−	−	+
Ustilago reticulata	+	−	−	−	−	−	−
Ustilago sorghi	−	−	−	−	−	−	+
Ustilago striiformis	+	−	−	−	−	−	−
Total number of species	9	2	1	2	2	1	8

ACKNOWLEDGMENTS

I express my sincere thanks to Mr. E. J. Bryan, Jr., Curator of the Bernice J. Bishop Museum Herbarium, for working facilities and for loans of specimens; to Dr. Gladys E. Baker, Professor of Botany, University of Hawaii, and to Mr. E. T. Ozuki, State of Hawaii Plant Quarantine Inspector, for loans of specimens from HONO and HONQ, and to Dr. O. Degener and Dr. M. Aragaki for comments on my manuscript. I am also indebted to the State Department of Forestry for permission to make collections in the forest reserves, and to the superintendents of the Haleakala and Hawaii Volcanoes National Parks for permission to collect in the park areas. The type of *Tolyposporium mauritianum* was kindly loaned by IMI.

LITERATURE CITED

CIFERRI, R. 1931. Quinta contribuzione allo studio degli Ustilaginales. Annales Mycologici, vol. 29, pp. 1–74.

ITO, S. 1935. Notae mycologicae Asiae Orientalis II. Transactions of the Sapporo Natural History Society, vol. 14, pp. 87–96.

LINDEBERG, B. 1959. Ustilaginales of Sweden (exclusive of the Cintractias on Caricoideae). Symbolae Botanicae Upsalienses, vol. 16, no. 2, pp. 1–175.

LING, L. 1949*a*. A second contribution to the knowledge of the Ustilaginales of China. Mycologia, vol. 41, pp. 252–267.

——— 1949*b*. Taxonomic notes on Asiatic smuts—I. Sydowia, vol. 3, pp. 123–134.

——— 1950. Taxonomic notes on Asiatic smuts—II. Sydowia, vol. 4, pp. 74–80.

MÄKINEN, Y., and L. HIETAJÄRVI. 1965. On Finnish micromycetes. 5. *Albugo candida* in Finland, with special reference to the variation in the size of the conidia. Annales Botanici Fennici, vol. 2, pp. 33–46.

MUNDKUHR, B. B., and M. J. THIRUMALACHAR. 1946. Revisions and additions to Indian fungi. Mycological Papers, Imperial Mycological Institute, vol. 16, pp. 1–27.

PARRIS, G. K. 1938. Miscellaneous fungus diseases and insect pests. Annual Report, Hawaii Agricultural Experiment Station, 1936–1937, pp. 43–45.

——— 1939. Miscellaneous plant diseases. Annual Report, Hawaii Agricultural Experiment Station, 1937–1938, pp. 40–42.

——— 1940. A check list of fungi, bacteria, nematodes, and viruses occurring in Hawaii, and their hosts. Plant Disease Reporter, Supplement 121, pp. 1–91.

PETRAK, F. 1953. Beiträge zur Pilzflora von Hawaii. Sydowia, vol. 7, pp. 381–409.

STEVENS, F. L. 1925. Hawaiian fungi. Bernice P. Bishop Museum Bulletin 19, pp. 1–189.

SYDOW, H. 1939. Novae fungorum species—XXVII. Annales Mycologici, vol. 37, pp. 197–253.

SYDOW, H., and P. SYDOW. 1919. Mykologische Mitteilungen. Annales Mycologici, vol. 17, pp. 33–47.

THIRUMALACHAR, M. J. 1950. Notes on some Indian Ustilagineae—II. Lloydia, vol. 13, pp. 173–178.